Technique for Aortic Valve Replacement With Bioprosthetic and Prosthetic Valves

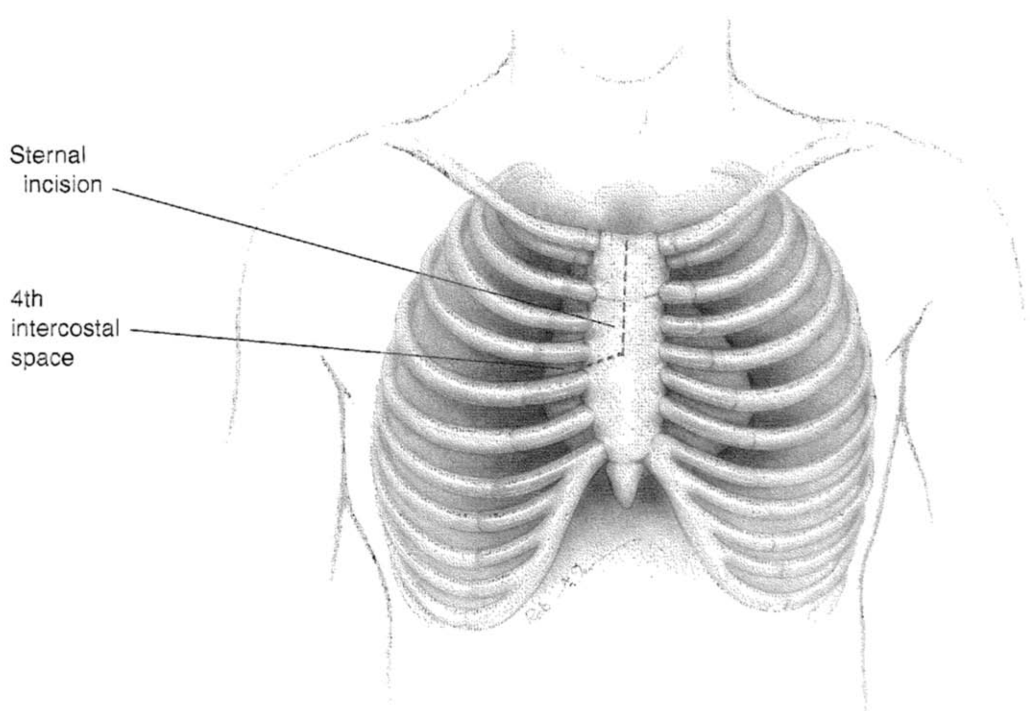
Richard J. Shemin, MD

This article illustrates my technique for aortic valve replacement with a bioprosthesis and a bileaflet prosthetic valve. The technique is based on sound surgical principles and on extensive personal experience, and has been used by many cardiothoracic surgeons with excellent results. The primary surgical goal is to provide exposure of the aortic valve so that valve excision, complete debridement, and secure implantation can be accomplished.

Standard exposure of the heart for aortic valve replacement is through a median sternotomy. The pericardium is opened longitudinally in the midline from the reflection over the aorta to the diaphragm, where it is opened to either side. The pericardial edges are sutured to the sternotomy wound, creating a pericardial cradle.

In the past several years, less-invasive incisions have been used for operations on the aortic valve and ascending aorta. After trials with parasternal, transsternal, and intercostal incisions, I have found that an upper ministernotomy with the sternal incision deviating into the right 3rd or 4th intercostal space (Fig. 1) provides the best exposure with minimal destruction to the chest wall and minimal postoperative discomfort. Essentially, all aortic root procedures, as well as ascending and/or transverse arch aortic aneurysm resections, with or without circulatory arrest can be performed through this incision. All aortic valve procedures also can be performed, including the Ross procedure and homograft root placement. To enhance exposure of the pulmonary artery when performing the Ross procedure, deviating the sternal incision into the left 3rd or 4th interspace as well as the right side is helpful. This approach preserves and usually protects the internal thoracic arteries.

Cannulation for cardiopulmonary bypass is per-

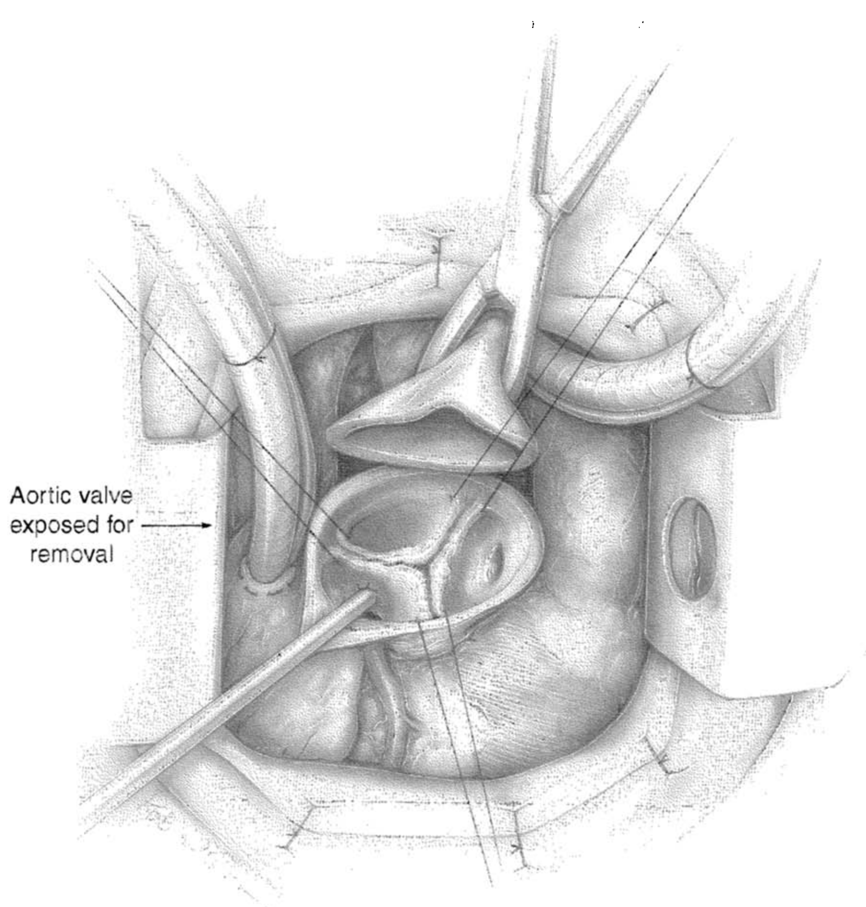


1 A small-diameter, two-staged cannula with thin walls provides excellent venous drainage without the need for active suction on the venous side of the pump. This reduces the complexity and cost of the pump setup. The dotted line shows the sternal incision used to expose the aorta for aortic root operations. The overlying skin incision is 3-4 cm in length.

formed after systemic heparinization by placing the arterial cannula into the ascending aorta and placing a two-stage venous drainage cannula into the right atrium.

Myocardial protection during aortic cross-clamping is provided with a combination of mild systemic hypothermia (34°C), administration of cold (4°C) high potassium (30 mEq/L), and administration of blood or crystalloid cardioplegia either antegrade, retrograde, or selectively into each coronary ostia. Topical hypothermia with continuous irrigation of cold (4°C) saline solution within the pericardium is used only in complete sternotomy procedures. Left ventricular decompression can be performed by venting the left-sided cardiac chambers through a catheter inserted into the left atrium via the right superior pulmonary vein. To minimize air in the heart, I prefer to not vent the left atrium; one can either not vent at all or use pulmonary artery venting. Air maneuvers are limited with minimal access approaches. The goal is to reduce the active suction behind the mitral valve and thus minimize the air rising into the pulmonary veins. CO_2 infusion into the surgical site further reduces air in the cardiac chambers.

SURGICAL TECHNIQUE



2 See legend on opposite page.

2 This exposure of the surgical field via a ministernotomy shows the cardiopulmonary bypass cannula positions and the placement of a soft-jawed aortic crossclamp. Excellent exposure is obtained by transecting the aorta above the sinotubular ridge, allowing the proximal aortic root to rotate to enhance the surgeon's view of the valve. Transection of the aorta is standard procedure in all of my aortic valve operations except in cases where severe calcification of the ascending aorta necessitates a modified aortotomy. Separation of the aorta and pulmonary artery before cross-clamping facilitates aortic transection.

Simple traction sutures are placed at the valve commissures to further expose the aortic valve. The pathology of the valve is observed. Excision of the valve is performed using scissors and a high-vacuum sucker with an open tip to meticulously scavenge any loose particulate debris.

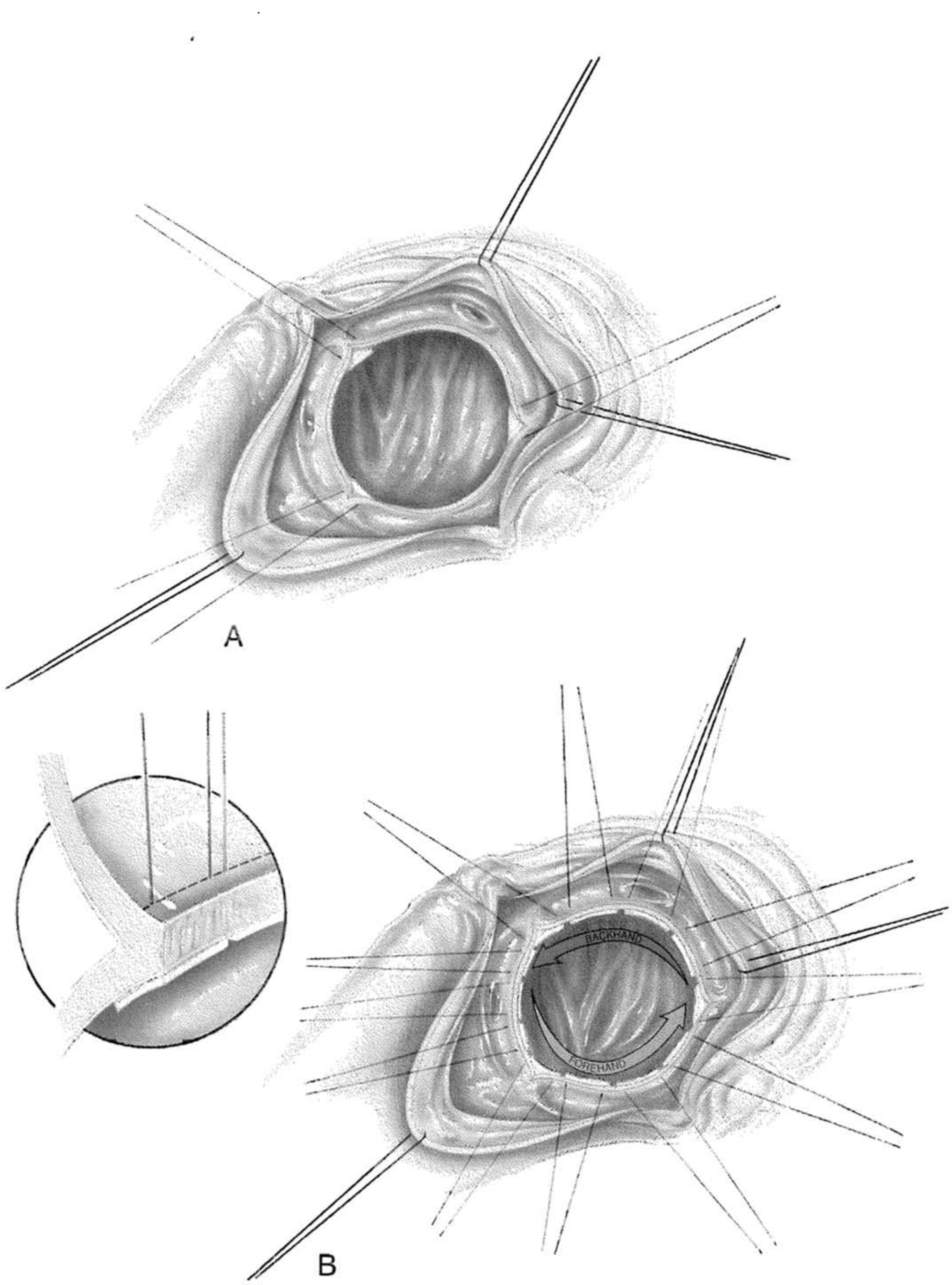
The excision is begun behind the calcific deposits in the leaflets. The discovery of calcific extension into the valvular annulus and the ventricular surface of the anterior mitral valve leaflet will require further debridement after the leaflet tissue is removed. Complete annular debridement is essential to restore annular pliability and to ensure secure and accurate placement of sutures.

Cardioplegia is readministered every 20 to 30 minutes during the cross-clamping period. Retrograde cardioplegia is convenient and does not need to be paused during valve implantation. When cardioplegia is to be readministered via the coronary ostia, it usually can be conveniently delivered during natural breaks in the procedure. This may be done after valve leaflet excision and annular debridement, after suture placement in the annular tissue, or after suture placement into the sewing cuff of the bioprosthesis. During cardioplegia administration, the left ventricular cavity is irrigated with 500 ml of 4°C saline solution poured through the aortic root to enhance endocardial cooling and flush any residual debris from the left ventricle. This irrigation is repeated during each of the natural breaks in the procedure described earlier.

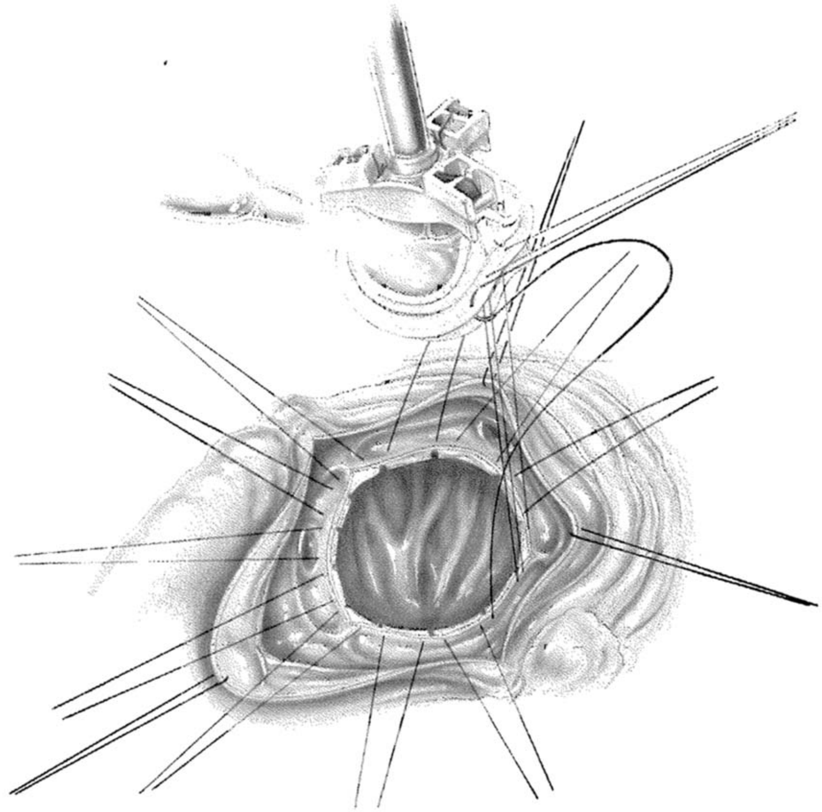
The annulus is sized using calibrated valve sizers. The sizers should fit comfortably within the annulus. My suturing technique for bioprosthetic valves uses pledgeted 2-0 braided double-armed sutures. Horizontal mattress sutures are placed with the pledget located below the aortic valve annulus (ventricular side). With this suture placement technique, it is only necessary to ensure a comfortable fit of the vertical extension of the sizer into the left ventricular outflow tract. The horizontal flange on the sizer representing the sewing cuff extension sits on the aortic side of the annulus below the coronary orifices.

An alternate technique places the pledget on the aortic side of the annulus. To size the annulus for this technique, ensure that the appropriate sizer passes comfortably into the left ventricular outflow tract through the annulus. This includes the horizontal sewing cuff extension (intra-annular technique). In general, a larger-sized valve is chosen for a given annulus when a suturing technique that places the pledget on the ventricular side of the annulus (supra-annular technique) is used.

After the appropriate valve size is determined, the valve is aseptically removed from the container. Appropriate rinsing of the bioprosthesis is begun.



3 (A) Suture placement begins by placing the first three sutures into the annulus at each of the commissures. These sutures help expose the annulus and aid placement of the remaining sutures. For convenience, I use sutures of two colors (illustrated in blue and green). Thus, the three commissural sutures are the same color. (B) The remaining sutures are placed. Usually, three equally spaced horizontal mattress sutures are placed between each of the previously placed commissural sutures. Note the use of alternating colored sutures and the needle position (backhand vs. forehand, from the perspective of a right-handed surgeon) to aid suture placement. The inset shows the horizontal mattress suture with the pledget on the ventricular side of the aortic valve annulus. After all sutures are placed, the left ventricle is irrigated with cold (4°C) saline solution. (Reprinted with permission from Shemin RJ: Technique for Aortic Valve Replacement With the Carpentier-Edwards Porcine Aortic Valve Bioprosthesis. Irvine, CA, Baxter Healthcare Corp, 1991.)



4 After the bioprosthesis is thoroughly rinsed, the valve is thoroughly inspected for any irregularity of the leaflets or other defects. Suture placement into the bioprosthetic valve sewing cuff is begun at the commissure. I start with the suture placed in the annulus at the commissure between the right and noncoronary cusps, as illustrated. Suturing is done in a clockwise direction for the noncoronary and left coronary cusps and counterclockwise for the right coronary cusp. If all of the intercommissural distances are equal, then suture placement into the sewing cuff should mirror suture placement in the annular tissue. The sutures should extend down midway into the sewing cuff to ensure secure fixation. Both the inflow and outflow sides of the bioprosthetic aortic valve tissue should be frequently irrigated with saline solution to prevent tissue drying.

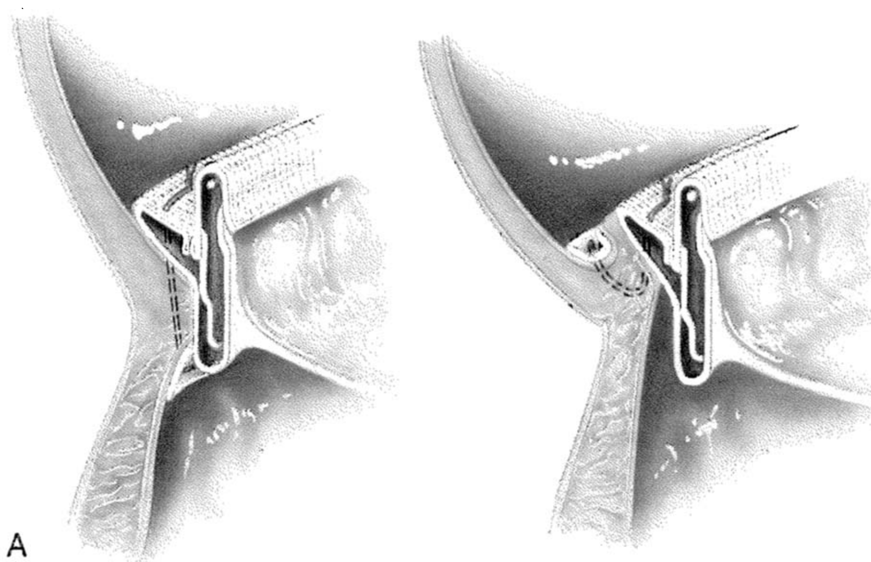
After suture placement is completed, the final irrigation of the left ventricular cavity with 4°C saline solution is performed. If additional cardioplegia administration is required, this is a convenient time in the procedure to provide it.

The valve is lowered into position with the valve sutures held tight and upright. The holding sutures of the valve to the handle are cut with a knife blade. The valve holder is removed, with care taken to keep the valve from dislodging out of the annulus.

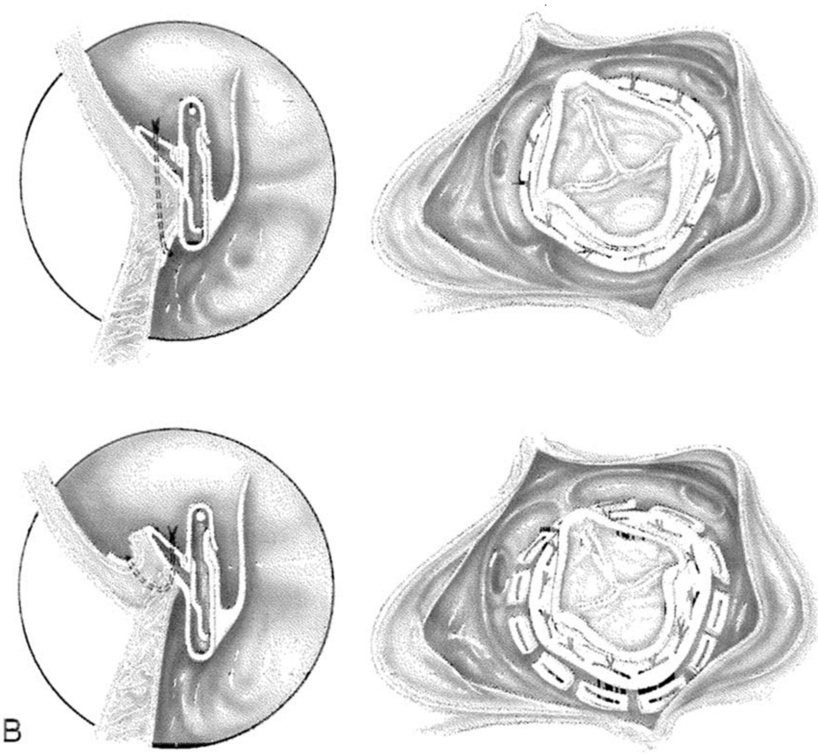
The sutures are individually tied by pulling up on each pair and ensuring that they slide easily. This confirms that the pledget is seated without a twist and that the adjacent suture has not been snared. The suture is then securely tied. The alternating colored sutures helps the surgeon identify the next suture to be tied. I tie the suture placed at the commissure between the left and right cusps first, then continue suturing counterclockwise beneath the left coronary artery, in the noncoronary cuspal area, and finally, in the right coronary cuspal area.

When cutting the excess suture material beyond the knot, care must be taken to ensure that the suture tails are not too long. Excessive suture tails could damage leaflet tissue during valve opening.

Before closing the aorta, the surgeon checks to ensure that the valve is well seated and that the perivalvular spaces are not present. Finally, the valve position is rechecked to ensure no risk for obstruction of the coronary ostia. (Reprinted with permission from Shemin RJ: Technique for Aortic Valve Replacement With the Carpentier-Edwards Porcine Aortic Valve Bioprosthesis. Irvine, CA, Baxter Healthcare Corp, 1991.)



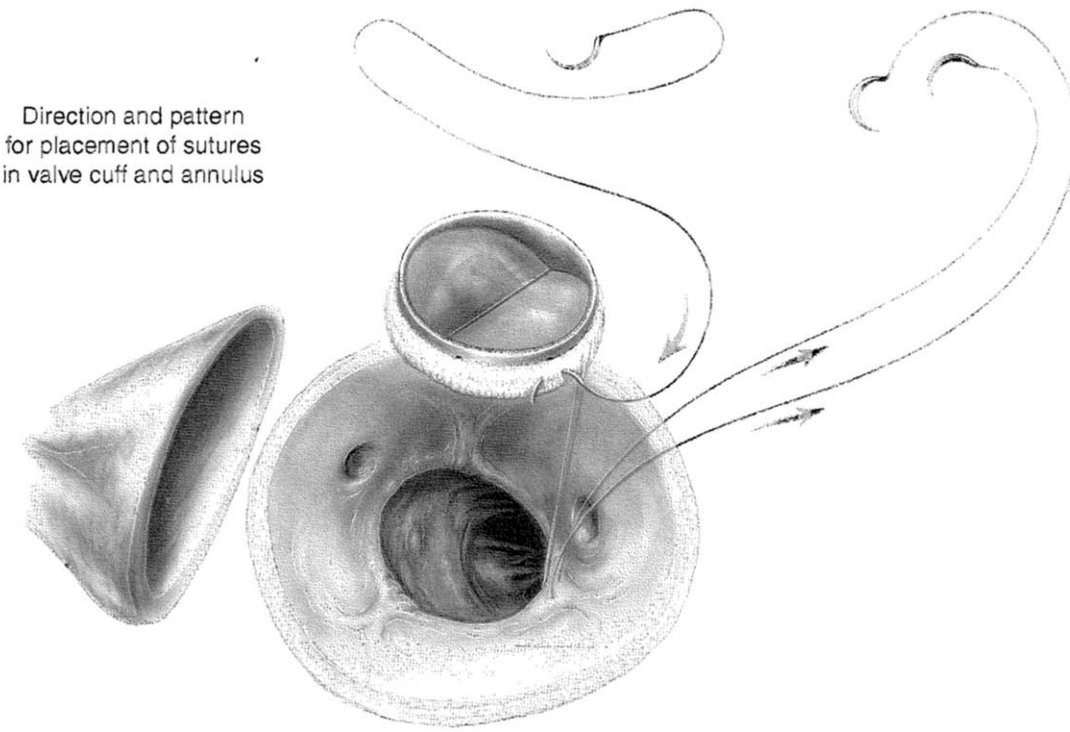
5 (A) This shows the position of the sewing cuff when the sutures are placed through the annulus tissue in a horizontal mattress configuration and the pledget is either on the left ventricular side or aortic side of the annulus. The preferred technique (supra-annular) with the left ventricular position for pledget placement allows use of a larger valve for a given annulus. Moreover, if the pledget is placed on the aortic side of the annulus when the sutures are tied, part of the sewing cuff becomes intra-annular. This causes the valve housing to extend farther below the sewing cuff into the outflow tract than would occur with the other technique. (Reprinted with permission from Shemin RJ: Technique for Aortic Valve Replacement With the Carpentier-Edwards Porcine Aortic Valve Bioprosthesis. Irvine, CA, Baxter Healthcare Corp, 1991.)



B

5 (continued) (B) This shows the final position of the valve within the aorta with both techniques of suture placement before closure of the ascending aorta. The suturing technique that I use while implanting a bileaflet mechanical valve is based on an intra-annular position of the prosthesis including the sewing cuff. The excellent hemodynamic profiles of these valves, even in small sizes (≥21 mm), allows the surgeon to avoid the supra-annular technique previously described. Mechanical valves are less likely to produce leaflet obstruction when the intra-annular technique is used. If the annulus measures 19 or 21 mm, then either the annulus must be enlarged or a supra-annular technique performed to allow a use of larger mechanical prosthesis.

For the intra-annular technique, an everting pledget or nonpledgeted horizontal mattress sutures are placed with the pledget on the aortic side of the annulus. The sutures can then be placed circumferentially around the prosthetic valve sewing cuff. (Reprinted with permission from Shemin RJ: Technique for Aortic Valve Replacement With the Carpentier-Edwards Porcine Aortic Valve Bioprosthesis. Irvine, CA, Baxter Healthcare Corp, 1991.)



6 I prefer to use a faster and simpler modification of the technique where a suture is placed as a horizontal mattress bite into the sewing cuff, advancing the needle to a desired width. Then that needle is reloaded and placed in the aortic valve annulus from the ventricular side to the aortic side, advancing the corresponding distance as determined by the width of the original bite taken in the sewing cuff. The second needle of the double-armed suture is then placed into the annulus near the previous suture. All sutures are similarly placed circumferentially around the sewing cuff and annulus. I work clockwise starting from the commissure between the right and noncoronary cusp. This technique requires only three needle passes per suture, as opposed to four passes in the more standard technique. Moreover, the sutures are placed first into the sewing cuff and then into the tissue annulus before the next suture is placed. When the valve is lowered into its intra-annular position and the sutures are tied, knots and the cut ends are on the aortic side of the annulus, not on the sewing cuff, and thus are a significant distance from the mechanical leaflets. The intra-annular valve position minimizes tissue and suture interference with leaflet motion.

The transected aorta is closed using a running layer of 5-0 double-armed monofilament suture. The suture line ends so that the suture is tied at the highest point of the ascending aorta.

The patient's head is then placed in a dependent position, and the left side of the heart is allowed to fill with blood. Ventilation further fills the heart with blood and helps displace air. As the aorta is unclamped while cardiopulmonary flow is reduced, the aortotomy is held open using the tips of forceps in the center at highest point to promote air venting from the aortic root.

The pump flow is returned to normal, and the aortotomy suture is tied. A small venting catheter in the ascending aorta is maintained on suction to allow continued air evacuation until the patient is totally weaned from cardiopulmonary bypass and transesophageal echocardiography demonstrates no residual air within the cardiac chambers.

Attempts to aspirate any residual air from the left atria can be accomplished by easy access to the dome of the left atrium behind the aortic root. Left ventricular apical aspiration is not possible in minimal access aortic valve surgery. Manipulation of the operating room table position (i.e., head up or down, tilted left or right) and partial bypass with aortic root suction facilitates air removal before cardiopulmonary bypass is discontinued.

Transesophageal echocardiography is used before protamine administration and decannulation to confirm adequate valve function and complete air evacuation.

From the Department of Cardiothoracic Surgery, Boston Medical Center, Boston University School of Medicine, Boston, MA.

Address reprint requests to Richard J. Shemin, MD, 88E. Newton St, Dept of Cardiothoracic Surgery, Boston Medical Center, Boston, MA 02118.

1522-2942/00/0501-0001$35.00/0
doi:10.1053/2000.otct.21362